UNIVERSIDADE FEDERAL DE SERGIPE

PRÓ- REITORIA DE PÓS-GRADUAÇÃO E PESQUISA

MESTRADO EM EDUCAÇÃO FÍSICA

ANÁLISE DE DIFERENTES MÉTODOS DE RECUPERAÇÃO EM RELAÇÃO AO TREINO E COMPETIÇÃO NO JIU-JITSU

LILLIAN BEATRIZ FONSECA DOS SANTOS

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Dissertação apresentada ao Programa de Pós-Graduação em Educação Física da Universidade Federal de Sergipe como requisito parcial para obtenção do grau de Mestre em Educação Física.

Orientador: Prof. Dr. Felipe José Aidar Martins

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Aprovada em _____/_____/_____

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Resumo

Introdução:esportes competitivos exigem uma preparação física extenuante que ocasiona em seus atletas uma série de alterações fisiológicas negativas (dano muscular, diminuição na capacidade de gerar força, etc), visando minimizar esses efeitos é necessário encontrar estratégias que auxiliem a aceleração do processo de recuperação pós-treino, possibilitando a manutenção no nível de treinamento estimado para atingir a demanda competitiva**. Objetivo:**analisar diferentes métodos de recuperação em relação ao treino e competição de Jiu-Jítsu. **Métodos:**a amostra foi composta por 10 indivíduos do sexo masculino, com idade entre 18 e 29 anos, praticantes das modalidades, com experiência em competições,houve uma simulação de treino e competição no primeiro momento metade dos indivíduos foram submetidos ao tratamento com a Crioterapia, a outra metade permaneceu em repouso. Uma semana depois os houve o cruzamento dos grupos para que todos passassem por todos momentos. Foi realizada coleta de sangue em diferentes momentos para medir os marcadores de dano muscular antes, imediatamente depois, 24h e 48h pós da realização de treino e simulação de competição. **Resultados:**a recuperação com Crioterapiamostrou-sebenéfica para Jiu-Jítsu, havendo redução nos níveis de LDH e de percepção de dor muscular, bem como auxiliou na recuperação da potência nos membros superiores e inferiores 24h pós-intervenção, bem como o modelo de treino avaliado consegue acompanhar de forma satisfatória as exigências de uma competição. **Conclusão**: aCrioterapiapode ser utilizada como ferramenta de recuperação pós-treino para auxiliar professores e atletas na manutenção do programa de treinamento, que por sua vez possuem alta correlação com a demanda exigida em uma competição.

Palavras Chave:jiu-jítsu, dano muscular, recuperação, crioterpia

Abstract

Introduction: Competitive sports require strenuous physical preparation that causes in their athletes a series of negative physiological changes (muscle damage, decrease in ability to generate strength, etc.), aiming to minimise these effects is necessary Find strategies that assist the acceleration of the workout recovery process, enabling the maintenance at the level of training estimated to achieve competitive demand. **Objective:** To analyze different methods of recovery in relation to the training and competition of Jiu-jitsu. **Methods**: The sample was composed of 10 male males, aged between 18 and 29 years, practitioners of modalities, with experience in competitions, there was a simulation of training and competition in the first moment half of the individuals were subjected to Treatment with cryotherapy, the other half remained at rest. A week later there was the crossing of the groups so that everyone would pass through every moment. Blood collection was performed at different times to measure the markers of muscle damage before, immediately after, 24h and 48 hours of performing training and simulation of competition. **Results:** Recovery with cryotherapy proved beneficial for Jiu-jitsu, with reduction in levels of LDH and perception of muscular pain, as well as assisted in the recovery of power in the upper and lower members 24h post, as well as the model of rated training can follow the requirements of a competition satisfactorily. **Conclusion**: Cryotherapy can be used as a workout recovery tool to assist teachers and athletes in the maintenance of the training program, which in turn have high correlation with the demand required in a competition.

Key words: Jiu-jitsu, muscle damage, recovery, Criotherapy

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SUMÁRIO

1. INTRODUÇÃO GERAL

O esporte, impulsionado pela mídia, tem se tornado cada vez mais popular, as lutas, por sua vez, tem o seu show a parte: *O MixedMartialArts (MMA)*, evento que proporciona aos espectadores um espetáculo onde dois atletas utilizam-se da combinação de técnicas de lutas diversas com o objetivo de vencer seu adversário, a modalidade não só entrou na programação televisiva da população como passou a ser inspiração que atrai adeptos a prática das lutas. Dentre as lutas mais procuradas podemos destacar as modalidades de *grappling*(lutas agarradas) dando destaque ao Submission, Wrestling, Judô e Jiu-Jítsu. (Rufino, 2010).

Segundo Brasil (2001), devido com a popularização das lutas o Jiu-Jítsu vem sendo cada vez mais procurado e praticado, o aumento na demanda, exige que os professores desenvolvam habilidades no processo de ensino-aprendizagem criando técnicas de intervenção eficazes que atendam os seus alunos incentivando a manutenção da atividade, a partir do objetivo de cada aluno, seja ele um praticante que busca melhorias na saúde e qualidade de vida ou aquele que tem como foco as competições e o rendimento.

A demanda crescente gera também a necessidade de estudos específicos da modalidade que consigam auxiliar os professores, técnicos e instrutores na construção de um bom programa de treinamento, mesmo sendo um esporte em ascensão, por muitos anos o Jiu-Jítsu foi marginalizado, sem visibilidade social, consequentemente, isso acarretou em uma bagagem científica singela, que não atende as exigências do cenário atual tornando evidente a necessidade de estudos sobre o Jiu-Jítsu que proporcionem melhoria na qualidade do treinamento, desta forma, o esporte não irá crescer só em número de praticantes, mas também em qualidade e nível técnico.

O Jiu-Jítsu competitivo exige do atleta uma elevada carga de treinamento é comum que os treinos aconteçam todos os dias, duas vezes por dia, seis dias por semana, a preparação física extenuante leva o atletas muitas vezes ao seu limite, o que, dia após dia, impede que o nível de treinamento seja mantido, diminuindo as chances de alcançar os objetivos planejados (Badillo, 2001). Diante disto, é de suma importância entender a demanda da preparação física e encontrar estratégias para minimizar os déficits provocados por ela, neste casoanalisaremos a Crioterapia como possível ferramenta para auxiliar na recuperação da força dos atletas, além de correlacionar o treino e a competição para entender e atestar se o modelo de treino adotado consegue suprir a demanda do atleta na competição.

A importância desse trabalho reflete em criar estratégias que auxiliem os profissionais da área no desenvolvimento de programas de treinamento onde os objetivos do rendimento sejam atendidos, ao mesmo tempo em que a saúde do atleta seja preservada, além de contribuir no amparo científico da modalidade engrandecendo o nível do esporte.

1.1Revisão de Literatura

1.1.1 O Jiu-Jítsu

Mesmo existindo controversa, a história mais aceita sobre o Jiu-Jítsu data que o mesmo teve seu início cerca de dois mil anos atrás, na Índia onde monges budistas que não podiam usar armas para defesa, desenvolveram uma série de golpes de imobilizações e torções que permitiam que eles, homens magros e de baixa estatura, pudessem se defender dos constantes ataques que sofriam por invasores e ladrões (Gurgel, 2000).

O Jiu-Jítsu, que tem como significado “arte suave” foi atravessando fronteiras, passando pela China e mais tarde chegando ao Japão onde passou a ser desenvolvido e popularizado, introduziu-se o uso do quimono e a arte começou a ser praticada por nobres e samurais.

Em 1914 o Jiu-Jítsu chegava ao Brasil através de MisuyoEsaiMaeda, conhecido como Conde Koma, ele começou a ensinar a arte suave na cidade de Belém do Pará onde conheceu Gastão Gracie, este, estimulou seus filhos Carlos e

Hélio na prática do esporte. Anos mais tarde eles adotaram o Jiu-Jítsu como profissão e estilo de vidapassando a divulgar a superioridade da sua luta através de desafios em combates sem regras onde demonstravam a superioridade da sua luta tornando-a cada vez mais popular (Gracie, et al 2008).

Gracie (2008) conta que os irmãos Gracie ensinavam um Jiu-Jítsu diferente daquele que havia sido aprimorado no Japão, a família solidificou suas academias através do refinamento da arte, o que levou Carlos Gracie a mudar as regras da modalidade, criando assim o primeiro caso de mudança de nacionalidade em uma modalidade de combate. Nascia então o Jiu-Jítsu Gracie, o Jiu-Jítsu Brasileiro. Esta nova modalidade, modificada, tornou-se uma das lutas mais praticadas no Brasil e no mundo. Em meio a tantas mudanças o Jiu-Jítsu tornou-se uma modalidade competitiva, individual.

Podemos definir o Jiu-Jítsu como uma modalidade predominantemente realizada no solo, tendo poucos momentos de luta em pé (Bernardi et al 2009), onde o objetivo é projetar o adversário dando continuidade ao combate através da execução de técnicas próprias da arte. O uso da roupa específica, conhecida popularmente como quimono, é obrigatório.

Durante os combates, o objetivo é conseguir neutralizar o adversário através de imobilizações, estrangulamentos, torções nas articulações e projeções ao solo. Não são permitidos golpes traumáticos, como: socos, chutes, dedos nos olhos, ou qualquer outro considerado desleal.

As categorias são subdivididas por idade, faixa, peso e sexo, por exemplo: a categoria adulto comporta atletas entre 18 e 29 anos com as faixas branca, azul, roxa marrom e preta (separadamente), os pesos variam em 9 subdivisões (galo, pluma, pena, leve, médio, meio pesado, pesado, super pesado e pesadíssimo) estes pesos variam de acordo com o sexo do atleta. Os tempos de luta também se adéquam a idade e faixa e cada categoria, variando entre 5 e 10 minutos (CBJJ, 2018).

Ao iniciar o combate a vitória mais desejada é aquela que vem por finalização, que é quando um dos atletas faz outro desistir antes do tempo final previsto para o combate, mas, a luta também pode ser vencida por pontos que são alcançados através da estabilização de raspagem, passagem de guarda, queda, pegada pelas cosas, montada e joelho na barriga, todas essas posições quando executadas de forma efetiva mostrando domínio sobre o adversário somarão pontos, caso o domínio não seja total o atleta receberá apenas vantagens que servirão para critério de desempate(Carmo, 2013).

Weineck (2012) corrobora que a competição exige do atleta uma série de adaptações fisiológicas que possibilitem um melhor rendimento, para isso, é necessário trabalhar vários tipos de força muscular, potência, reação, coordenação, resistência, dentre outras habilidades, tornando necessárias sessões de treinamentos extenuantes que podem causar fadiga e impedir que o programa de treinamento seja concluído de forma satisfatória, interferindo negativamente na busca pelos resultados almejados.

Quando o lutador ultrapassa seu limite chegando a uma fadiga muscular ocorre um déficit na capacidade de desempenho físico e psicológico, quanto maior o nível de fadiga, maior os prejuízos para o treinamento, ela pode alterar a capacidade de gerar ou manter a força em situações de treinos e competições. A manutenção na qualidade e no nível elevado de treinamento não depende só dos atributos físicos do atleta, mas, também de estratégias para minimizar lesões e a fadiga causada pelo dano muscular gerado pelas duras sessões de treino (Glasgow, 2014)

1.1.2 O Treino e a recuperação

No que se refere ao treino e a prática da modalidade, existe um risco significativo de ocorrência de lesões em artes marciais (Arruda, 2006), devido a diversos fatores que envolvem um esporte de contato e fatores externos que podem potencializar e tornar recorrente a incidência de lesões ao logo de treinos e competições, uma forma de minimizar tal problema é através da qualificação e a supervisão sob a prática, assim como a presença de um ambiente de treinamento ou competição seguro e regulamentos rígidos em competições são fatores críticos na epidemiologia de lesões nas artes marciais.

Dada a existência de risco de lesões em artes marciais, como o Jiu-Jítsu e o Judô tornam-se interessante o incentivo a novos estudos na área com finalidade de originar programas preventivos específicos para combater as lesões esportivas (Baffa, 2002).

Neste sentido a preparação física de lutadores de alto rendimento requer elevada carga de esforço físico (Detanico; et al. 2014). Diante de tal constatação, o dano muscular advindo do exercício de alta intensidade tem sido alvo de uma série de investigações, por conta da interferência que causam no desempenho esportivo, tornando as estratégias de recuperação cada vez mais importantes na prática esportiva.

1.1.3 O Dano Muscular

O dano muscular surge principalmente a partir de ações excêntricas causando déficit na atividade das fibras musculares e do tecido conjuntivo, ocasionando uma queda na capacidade do indivíduo em gerar força, diminuição na amplitude do movimento além de contribuir na aparição da dor muscular de início tardio. Então, sendo assim, o dano muscular pode se considerado a resposta inflamatória do organismo ao exercício físico intenso e contínuo (Berton R, et al, 2012)

Assim, o dano muscular seria desencadeado por fatores estressantes que atuam na liberação de toxinas que dificultam a distribuição de energia necessária para atuar no bom funcionamento da estrutura celular e na estabilização da membrana celular, tais alterações metabólicas que dificultam a liberação de ATP, favorecendo o aparecimento da lesão muscular (Cordova A, 2000).

Para mensurar o dano muscular, são utilizados marcadores diretos e indiretos. As medidas diretas, são avaliadas através de imagens feitas por ressonância magnética ou análise de amostras através da biópsia. Já entre as medidas indiretas mais comuns encontramos, o uso das escalas subjetivas de percepção, análise de enzimas plasmáticas (Foshini et al 2006), sendo estas adotadas para a avaliar o dano muscular em nosso estudo.

Dentre os marcadores de dano musculares mais investigados, pode-se citar a Creatina Quinase (CPK), a Lactato Desidrogenase (LDH) (Clarkson and Hubal 2002), a Aspartatoaminotransferase (AST) e a Alanina Aminotransferase (ALT)(Chishaki; et al. 2013).

O aumento da CPK ocasionado pela prática de exercícios está diretamente relacionado ao surgimento da dor muscular tardia, bem como a maior expressão de marcadores de lesão cartilaginosa. O aumento nas concentrações séricas desta enzima pós-exercício é inversamente proporcional à capacidade do músculo gerar força (Pinho Júnior; et al. 2014).

A LDH está presente em grande quantidade no músculo esquelético, pois esta enzima é responsável pela conversão anaeróbia do piruvato em lactato. A associação da LDH com o dano muscular encontra-se intimamente ligada ao aumento da concentração de CPK (Hausswirth; et al. 2011).

AST e ALT são enzimas hepáticas importantes para catabolismo de aminoácidos, apesar de pouco concentradas no músculo, o aumento da atividade destas estas enzimas ocorre durante o exercício intenso (Nazari; et al. 2014)aeróbio(Nie; et al. 2011) ou intermitente (Gaeini; et al. 2013), uma vez que o exercício intenso tende a aumentar o catabolismo protéico.

De fato, 2,5 horas de treino de judô resultam em aumento entre 15 a 42% na concentração sérica destas enzimas (Chishaki; et al. 2013). Uma vez que o volume de treinamento precisa ser mantido para o desempenho de alto rendimento, tem-se investigado métodos regenerativos para diminuir o dano muscular pós-exercício.

1.1.4 Recuperação pós-treino

A recuperação tem se mostradomuito importante no que se refere a preparação dos atletas, principalmente nos esporte de luta. Assim, estudos realizados demonstraram benefícios agudos da imersão em água gelada na preservação da força, diminuição do dano e dor muscular pós-treino e competição simulada de jiu-jítsu (Pinho Júnior; et al. 2014).

O uso da Crioterapiatorna-se cada vez mais comum no cenário esportivo, precisa-se investigar se essa alternativa de recuperação é realmente efetiva na regeneração muscular visando a manutenção dos treinos de uma forma positiva, ou se esta intervenção funciona apenas como um placebo sem benefícios que possam ser comprovados fisiologicamente(Bleakley; et al. 2012.

Sendo a imersão em água gelada amplamente empregada apesar de haver poucas evidências que suportem sua eficácia, sabe-se imersão em água gelada causa vasoconstrição periférica, o que reduz o fluxo metabólico decorrente do exercício e diminui a condução nervosa na musculatura exercitada, resultando em diminuição da dor muscular (Bleakley; et al. 2012).

Sendo assim, aumentar a velocidade de recuperação é uma importante estratégia, principalmente para atletas envolvidos em ciclos competitivos. Nos esportes de combates, em especial de domínio (i.e. judô, luta olímpica, jiu-jítsu), este tema torna-se relevante, pois devido os competidores estarem altamente expostos à lesão por trauma (Yard; et al. 2008).

Neste sentido, reduzir o dano muscular pós-treino aumentará a proteção à saúde e a integridade física do atleta, elevando, assim, as chances para que este consiga completar o ciclo de preparação estabelecido. No entanto, até o presente momento, os estudos encontrados sobre o tema são pouco conclusivos no que diz respeito ao efeito da Crioterapia sobre o dano muscular em lutadores.

1.1.5 Crioterapia

Entende-se por Crioterapia, toda aplicação de qualquer substância corporal que resulte na remoção do calor corporal, diminuindo a temperatura dos tecidos. Crioteapia significa "terapia com frio", e abrange toda prática terapêutica que utiliza aplicações de gelo e do frio. (Knight K, 2000)

Como técnicas de Crioterapia mais utilizadas, temos, as compressas de gelo para o atendimento de lesões imediatas, massagem com gelo e banhos de água fria (piscina fria ou imersão em balde com gelo), dentre outras, com nomes variados e objetivos terapêuticos diversos, por tanto, devemos adotar o termo Cioterapia num sentindo amplo, que abrange e engloba todas as outras técnicas praticadas a partir do uso do frioc(White 2003).

Dentre os usos da Crioterapia, Knight (2000), cita como mais comuns: a utilização como ferramenta na diminuição da dor e edema em caso de lesões agudas; possibilidade na antecipação da prática de exercício ativo na reabilitação de entorse articular aguda; redução de dor, edema, hipoxia secundária á lesão decorrentes de cirurgia ortopédica; minimização da dor ao injetar medicamentos etc.

Segundo Versey (2013), a aplicação e os efeitos da Crioterapia variam de acordo com os objetivos pelo qual a prática é utilizada, esses efeitos são divididos em sete categorias principais: diminuição da temperatura, diminuição do metabolismo, efeitos inflamatórios (diminuição ou aumento), efeitos circulatórios (diminuição ou aumento), diminuição da dor, diminuição do espasmo muscular e aumento da rigidez tecidual. Neste estudo, observaremos o comportamento dos efeitos da Crioterapia (dor, inflamação, etc) sobre uma vertente esportiva, sua utilização, benefícios e viabilidade como método de recuperação para atletas.

Na utilização da Crioterapia para tratamento de lesões agudas esportivas, o tecido é resfriado a uma temperatura de 1°C a 10°C, a diminuição do metabolismo é considerado o efeito mais importante para o atendimento imediato da lesão, devida a limitação da hipoxia secundária, essa diminuição no metabolismo, gera também, menor circulação, reduzindo a liberação de oxigênio, contribuindo para a hipoxia secundária. Também considera-se o frio benéfico nessa intervenção por diminuir os espasmos musculares e as dores (Fonda, 2013).

Para entender e utilizar ao máximo todas as possibilidades de uma modalidade terapêutica é preciso compreender as necessidades fisiológicas específicas do cenário a ser trabalhado, dentre as respostas benéficas da Crioterapia, a diminuição do metabolismo, inflamação, dor e espasmos, referente a lesão aguda esportiva promovem uma série de benefícios a seus pacientes, se olharmos por outro lado, esses mesmos benefícios podem ser testados para utilização na promoção da qualidade de vida dos atletas (Mustalampi et al 2012).

Visando expandir o uso e efeitos da Crioterapia e avaliando o cenário de preparação física pela qual os atletas se submetem, surge a necessidade de encontrar evidências que comprovem se tais benefícios do frio podem se estender a lesão provocada pelo exercício extenuante, passando a atuar como estratégia de recuperação, minimizando os danos provocados pelo treinamento de alta intensidade e facilitando a manutenção das atividades as quais os atletas deve cumprir dentro do tempo programado(Naughton M, et al 2017) .

1.1.6 Dor e Crioterapia

Vários conceitos surgem quando tentamos definir dor, nenhum deles consegue descrever nem medir a dor de forma precisa e adequada. Vamos adotar como base a idéia de dor como uma experiência sensorial e emocional desagradável, associada a um dano tecidual ou descrita em decorrência dele (Knight 2000).

Melzack e Torgerson (1971), descreveram quatro qualidades ou componentes da dor, são eles: sensorial (ou discriminativa), está relacionada a condução de impulsos dos órgãos do sentido na região periférica, para os centros reflexos ou superiores; afetiva (ou motivacional) é influenciada pelo estado mental, pelo tipo de personalidade, metas, desejos e expectativas do paciente; analítica (ou cognitiva) é o julgamento subjetivo geral de toda a experiência dolorosa; e a mista refere-se ás combinações anteriores.

Para mensurar os níveis de dor, é comum utilizar algumas ferramentas que quantificam e forma subjetiva através da avaliação do indivíduo sobre sua dor. Dentre os meios mais utilizados, podemos destacar o uso das Escalas Visuais Analógicas, que descrevem a dor através do dois pontos extremos, onde o indivíduo indicará o nível de dor que estão sentindo. As escalas visuais analógicas são classificadas como um meio concreto, sensível e reproduzível para expressar a magnitude da dor (Knight, 2000).

Grande parte do desempenho de um atleta esta ligada a ausência de dor, todo exercício livre de dor, permite uma ação mais vigorosa e eficaz, uma vez que esse sintoma se manifesta o atleta tende a retroceder. Sendo adiminuição da sensação de dor o principal efeito da Crioterapia (Fonseca, 2016), é viável testar seus efeitos como método de intervenção para aceleração da recuperação, associado a preparação física de atletas de Jiu-Jítsu.

Neste sentido apresentaremos a seguir os problemas e objetivos do nosso estudo. Para melhor expor nossos métodos e resultados as questões serão respondidas através de dois capítulos cada capítulo descreverá o tema de um dos estudos realizados.

1.2 Questões de Estudo

Os problemas que a presente dissertação almeja elucidar são os seguintes:

1) A recuperação através da imersão em água gelada apresenta diferenças em relação a recuperação passiva quanto ao dano muscular?

2) A recuperação através da imersão em água gelada apresenta diferenças em relação a recuperação passiva quanto a potência?

3) A simulação de treino atende a necessidade fisiológica exigida na competição?

1.3 Organização da Dissertação

O interesse em organizar este trabalho visa investigar e oferecer respostas que poderão melhorar a avaliação dos diferentes tipos de recuperação em relação ao treino e a relação destes com a simulação de competição sobre o dano muscular, força, fadiga.

Considerando a quantidade de dados recolhidos, o número de variáveis em estudo e, sobretudo, a diversidade das questões acima indicadas, optou-se por apresentar, nesta dissertação, dois estudos, que no seu conjunto permitem dar resposta às questões.

O estudo “1” intitulado “**Use of Cold-Water Immersion to Reduce Muscle Damage and Delayed-Onset Muscle Soreness and Preserve Muscle Power in Jiu-Jitsu Athletes**”, pretende responder asquestões # 1 e #2

O estudo “2”, intitulado “**Analysis of muscle damage and strength in two distinct methods in JiuJitsu athletes**”, pretende responder à questão #3.

Assim, no capítulo dois são descritos os estudos realizados. Cada estudo encontra-se dividido nas seções tradicionais do formato de artigo (Resumo, Introdução, Métodos, Resultados e Discussão).

Por último, nesta dissertação são apresentadas as conclusões finais, procurando dar resposta às questões em estudo, sugerindo implicações práticas e novas linhas de investigação.

1.4 Objetivo

1.4.1 Objetivo Geral

Analisar diferentes métodos de recuperação em relação ao treino e competição de Jiu-Jítsu.

OBSERVAÇÃO

Os artigos se apresentam na fora e no idioma como estão nas revistas publicado/submetido tendo em vista os efeitos legais uma vez que os direitos autorais dos mesmos não são de domínio dos autores, pertencendo as revistas em epígrafe conforme se verifica na presente dissertação.

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2. Estudos Realizados

2.1 Estudo 1

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original research

Use of Cold-Water Immersion to Reduce Muscle Damage and Delayed-Onset Muscle Soreness and Preserve Muscle Power in Jiu-Jitsu Athletes

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Context: Cold-water immersion (CWI) has been applied widely as a recovery method, but little evidence is available to support its effectiveness.

Objective: To investigate the effects of CWI on muscle damage, perceived muscle soreness, and muscle power recovery of the upper and lower limbs after jiu-jitsu training.

Design: Crossover study.

Setting: Laboratory and field.

Patients or Other Participants: A total of 8 highly trained male athletes (age = 24.0 ± 3.6 years, mass = 78.4 ± 2.4 kg, percentage of body fat = 13.1% ± 3.6%) completed all study phases.

Intervention(s): We randomly selected half of the sample for recovery using CWI (6.0°C ± 0.5°C) for 19 minutes; the other participants were allocated to the control condition (passive recovery). Treatments were reversed in the second session (after 1 week).

Main Outcome Measure(s): We measured serum levels of creatine phosphokinase, lactate dehydrogenase (LDH), aspartate aminotransferase, and alanine aminotransferase enzymes; perceived muscle soreness; and recovery through visual analogue scales and muscle power of the upper and lower limbs at pretraining, postrecovery, 24 hours, and 48 hours.

Results: Athletes who underwent CWI showed better posttraining recovery measures because circulating LDH levels were lower at 24 hours postrecovery in the CWI condition (441.9 ± 81.4 IU/L) than in the control condition (493.6 ± 97.4 IU/L; P = .03). Estimated muscle power was higher in the CWI than in the control condition for both upper limbs (757.9 ± 125.1 W versus 695.9 ± 56.1 W) and lower limbs (53.7 ± 3.7 cm versus 35.5 ± 8.2 cm; both P values = .001). In addition, we observed less perceived muscle soreness (1.5 ± 1.1 arbitrary units [au] versus 3.1 ± 1.0 au; P = .004) and higher perceived recovery (8.8 ± 1.9 au versus 6.9 ± 1.7 au; P = .005) in the CWI than in the control condition at 24 hours postrecovery.

Conclusions: Use of CWI can be beneficial to jiu-jitsu athletes because it reduces circulating LDH levels, results in less perceived muscle soreness, and helps muscle power recovery at 24 hours postrecovery.

Key Words: creatine kinase, cryotherapy, L-lactate dehydrogenase, martial arts, muscle power

Key Points

- Cold-water immersion may be beneficial to jiu-jitsu athletes because it decreased markers of muscle damage.
- Cold-water immersion reduced the perception of muscle pain.
- Cold-water immersion assisted in the recovery of the upper and lower limbs.
- Jiu-jitsu athletes could use cold-water immersion to improve performance and physiologic status, especially during training phases in which more intensive sessions are conducted and at the beginning of the season.

The physical preparation of high-performance combat-sport athletes requires high levels of physical effort.[1] However, strenuous exercise promotes biochemical and cellular changes that result in deterioration of the muscle structure, decreasing muscle power.[2,3] In this context, many investigators have studied muscle damage arising from high-intensity exercise because it interferes with sport performance.[3] Creatine kinase (CK), lactate dehydrogenase (LDH),[4] aspartate aminotransferase (AST), and alanine aminotransferase (ALT) are among the most studied serum muscle damage markers.[5] An increased level of exercise-induced CK is directly related to muscle pain, greater expression of cartilage injury markers,[6] and muscle disruption.[7] Furthermore, the postexercise increase in the serum concentration of CK is inversely proportional to the ability of the muscle to generate power.[8] Lactate dehydrogenase is present in large amounts in skeletal muscle because it is responsible for the anaerobic conversion of pyruvate into lactate. The association of LDH with muscle damage is linked closely to the CK concentration.[9] Aspartate aminotransferase and ALT are liver enzymes important for the catabolism of amino acids, and although they are at low concentrations in muscle, increased activity of these enzymes occurs during intense,[10] aerobic,[9] or

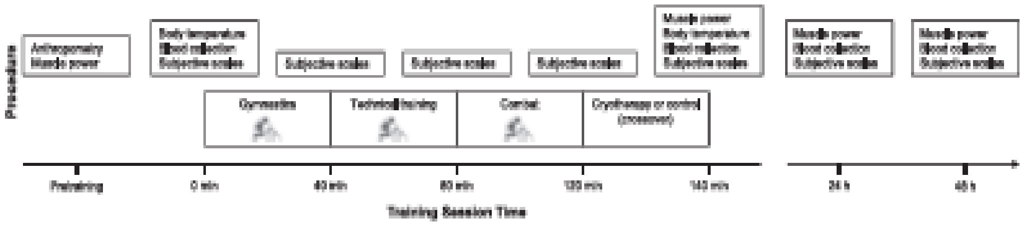

Figure 1. Organization chart of procedures used for data collection. Numbers on bars refer to procedures used before, during, and after training sessions.

intermittent exercise,[11] which increases protein catabolism. However, no authors, to our knowledge, have established correlations among muscle damage enzymes, perceived pain, and sport performance. Any relationship among these variables would provide some indication about variables that could be manipulated in future experiments to verify a possible causal effect.

In fact, 2.5 hours of judo training resulted in a 15% to 42% increase in the serum concentrations of these enzymes.[5] Given that training volume must be maintained for high-performance athletes, regenerative methods to reduce postexercise muscle damage have been investigated. Among these methods, cold-water immersion (CWI) has been used widely. It causes peripheral vasoconstriction, which reduces the metabolic outflow resulting from exercise, and decreases nerve conduction in the exercised muscle, resulting in decreased muscle soreness[12,13]; however, little evidence is available to support its effectiveness in improving physical performance.[13,14] In addition, Rupp et al[15] reported that CWI decreased muscle temperature faster than an ice pack, so this approach seems to be relevant to athletes conducting successive training sessions.

Increasing the recovery rate is an important strategy, especially for athletes involved in training cycles. In combat sports, particularly those involving grappling (judo, wrestling, jiu-jitsu), this factor is relevant because athletes are highly predisposed to traumatic injury.[16] Reducing posttraining muscle damage could increase protect the health and physical integrity of athletes, increasing their chance of achieving the goals established for a given preparation cycle. However, to date, studies published on this subject have been inconclusive about the effect of cryotherapy on muscle damage in combat-sport athletes. Authors[8] have demonstrated the acute benefits of CWI in preserving muscle power and decreasing muscle soreness and damage after training[17] and simulated jiu-jitsu competition.

Given the need for new alternatives that lead to better recovery, the effectiveness of cryotherapy for reducing muscle damage, which can accelerate recovery and enhance sport performance, should be tested. Therefore, the purpose of our study was to assess the effect of CWI after jiu-jitsu training on the perceived muscle pain, inflammatory response, and muscle power of the upper and lower limbs, as well as on the relationships among these variables. We hypothesized that this intervention would reduce perceived muscle soreness and the inflammatory response and would result in better preservation of muscle power. Moreover, we hypothesized that more perceived pain and an increased inflammatory response would correlate with performance decrement.

METHODS

Design

For this crossover study, 2 training sessions separated by 1-week intervals were carried out. The data-collection procedure is provided in Figure 1.

The training protocol represented a typical session, characterized by progressive and exhaustive effort. Each training session comprised the following structure: 40 minutes each of generalized exercises (calisthenics), technical training, and combat simulation. Generalized exercises included warmup exercises involving power, speed, and endurance. Technical training focused on specific jiu-jitsu movements: guard passes, sweeps, arm locks, projections, and submissions. Combat simulations consisted of matches with varied durations: three 2-minute matches, two 5-minute matches, two 7-minute matches, and one 10-minute match. This training model was similar to that used in other studies of judo[18] and jiu-jitsu.[17] All volunteers were familiarized with the training regime and procedures.

Participants

Based on our pilot study (N = 4) and on the available literature, we performed a representative analysis to determine the appropriate sample size based on the serum CK concentration, which was the main indicator of muscle damage. To achieve 80% statistical power, a minimum sample size of 8 participants would be necessary to detect a serum CK increase of 80 IU/L throughout the experimental period and 40 IU/L to detect differences among groups (Granmo 5.2; IMIM, Barcelona, Spain). We chose this variable for the calculations because it presented the greatest variation among those variables measured in our study; a detailed description is provided in the Muscle Damage Markers subsection. Furthermore, other researchers[19,20] have found high intrasample variability for this enzyme. Given the nature of our study, we estimated a sample loss of 30%. A total of 12 highly trained male jiu-jitsu competitors were selected. This sample had trained continuously in the 10 months before the experiment and participated in all 4 phases of the state championship. Athletes were selected according to the following criteria: (1) graduation as a blue or purple belt (for technical-level equalization), (2) participation in at least 3 competitions in the year before the study, and (3) not involved in any rapid weight-loss process before competition (because this practice can negatively affect physical performance).[21] Of the sample, 4 participants did not complete all study stages: 1 had a knee injury, and 3 refused recovery by CWI. Thus, the final sample consisted of 8 athletes (age = 24.0 ± 3.6 years, mass = 78.4 ± 2.4 kg, percentage of body fat = 13.1% ± 3.6%).

All participants provided written informed consent, and the study was approved by the Federal University of Sergipe Research Ethics Committee (protocol 01723312.2.0000.0058), according to the Brazilian Health Council on experiments with humans.

Pretesting Procedures

Before data collection, we assessed the anthropometric and upper and lower limb muscle power of the athletes. Body mass was measured on a scale (Soehnle, Sao Paulo, Brazil) with maximum capacity of 200 kg and precision of 100 g. Height was measured using a stadiometer coupled to the scale (accuracy of 1 cm). Body density was estimated indirectly (Lange Skinfold Caliper, Beta Technology, Santa Cruz, CA) using the equation of Thorland et al[22] for college wrestlers:

$$D(g/mL) = 1,1030 - [0.000815(SD)] + [0.00000084(SD2)],$$

where D is body density and SD is the sum of subscapular and abdominal skinfold thicknesses. Body fat percentage (BF%) was estimated using the equation of Brožek et al[23]:

$$BF\% = 457/D - 414.2.$$

Procedures

Fighters were instructed to refrain from training or any strenuous physical activity for 24 hours before the experiment. A standardized breakfast was served to all athletes 90 minutes before training. The goal of the standardized breakfast was to provide similar energy intake to all athletes, minimizing the effect of nutritional status on the effort exerted during each training session. This 880-kcal meal consisted of bread, a slice each of ham and mozzarella cheese, banana, 100 g of granola, and 200 mL of whole-milk strawberry yogurt. On the first day, half of the sample was selected randomly to receive CWI, and the other half was allocated to the control condition (passive recovery). Treatments were reversed on the second day of training. Immediately after the training session, athletes receiving the CWI condition remained immersed in the ice bath to the neck (6.0°C ± 0.5°C) for 16 minutes: 4 cycles of 4-minute immersion with a 1-minute interval between cycles, totaling a 19-minute intervention. This CWI protocol followed that applied by Santos et al.[17]

Measures

Muscle Damage Markers. Serum CK, LDH, AST, and ALT concentrations were measured as markers of muscle damage. We collected blood samples at pretraining, postrecovery, and 24 and 48 hours postrecovery. About 2 mL of blood were collected from the antecubital vein

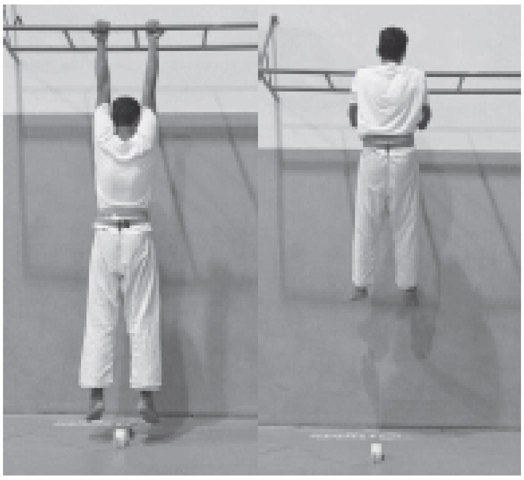

Figure 2. A, Initial and, B, Final positions of upper limb power test. [a] Encoder attachment point. [b] Encoder.

and stored in tubes containing coagulant gel (Vacuette; Greiner Bio-One, Campinas, Sao Paulo, Brazil). The blood rested for 30 minutes at room temperature to allow for coagulation and then was centrifuged at 2500 revolutions per minute for 8 minutes for serum separation. Biochemical measurements were performed in an automated analyzer (model Vitros 5600; Ortho Clinical Diagnostics, Raritan, NJ). Serum LDH (variation coefficient for same sample = 1.2%, accuracy = 1.909 IU/L), serum AST (variation coefficient for same sample = 1.8%, accuracy = 1.781 IU/L), and serum ALT (variation coefficient for same sample = 1.9%, accuracy = 1.909 IU/L) were measured using the multipoint kinetic technique. Serum CK was measured by the multipoint rate technique (variation coefficient for same sample = 1.5%, accuracy = 8.456 IU/L).

Upper Limbs Power Measurement. At pretraining, postrecovery, and 24 and 48 hours postrecovery, all athletes performed a muscle power test using a bar placed in the supine position and an encoder attached to their belts (model PFMA 3010e Muscle Lab System; Ergotest, Langesund, Norway). Three repetitions were performed, and the best result was selected for analysis. We calculated reliability from the baseline repetitions and found an intraclass coefficient (ICC) of 0.97 and a standard error (SE; 95%) of 17.5 W (2.5%). The initial and final positions of the upper limbs during the power test are shown in Figure 2.

Lower Limbs Power Measurement. At pretraining, postrecovery, and 24 and 48 hours postrecovery, all participants performed a lower limb power test using the countermovement jump (CMJ) on a jumping mat (Globus, Rome, Italy) according to the methods described by Bosco et al.[24] They made 2 attempts, and the best result was used for analysis. For the lower limbs, we calculated reliability from the baseline repetitions and found an ICC of 0.96 and an SE (95%) of 1.43 cm (2.8%).

Subjective Measurements. Athletes indicated perceived muscle soreness on a visual analog scale. This measurement was obtained at pretraining, posttraining,

Table 1. Muscle Damage Markers at Different Times of Jiu-Jitsu Training in the Cryotherapy and Control Conditions

	Time			
Marker, Mean ± SD	Pretraining	Postrecovery	24 h	48 h
Creatine phosphokinase, IU/L				
Cryotherapy	164.9 ± 72.4[e]	255.3 ± 103.6[c]	381.8 ± 110.6[d]	281.5 ± 82.2
Control	166.9 ± 72.0[e]	300.1 ± 108.3[c]	465.6 ± 117.8[d]	276.0 ± 39.5
Lactate dehydrogenase, IU/L				
Cryotherapy[a]	351.9 ± 30.4[e]	434.3 ± 28.2	441.9 ± 81.4[f,g]	378.4 ± 40.6
Control	353.0 ± 35.2[e]	489.3 ± 40.6	493.6 ± 97.4[f]	397.0 ± 51.5
Aspartate aminotransferase, IU/L				
Cryotherapy	22.4 ± 5.1[h]	27.4 ± 6.8	24.5 ± 3.9	24.8 ± 5.1
Control	23.1 ± 7.0[h]	29.0 ± 7.5	30.3 ± 6.4	25.9 ± 4.5
Alanine aminotransferase, IU/L				
Cryotherapy	23.6 ± 11.0	25.5 ± 11.4	25.5 ± 9.9	23.9 ± 8.1
Control	25.8 ± 19.0	25.5 ± 16.4	28.8 ± 14.8	26.1 ± 13.3

[a] Indicates cryotherapy condition was different from the control condition regardless of time ($P < .001$).
[b] Indicates different from the other times regardless of condition ($P < .001$).
[c] Indicates different from 24 h regardless of condition ($P < .001$).
[d] Indicates different from 48 h regardless of condition ($P < .001$).
[e] Indicates different from postrecovery and 24 h regardless of condition ($P < .001$).
[f] Indicates different from postrecovery and 48 h regardless of condition ($P < .01$).
[g] Indicates different from control condition for 24 h ($P < .001$).
[h] Indicates different from 24 h and 48 h regardless of condition ($P < .01$).

postrecovery, and 24 and 48 hours postrecovery using the methods described by Carvalho and Kowacs[25] (ICC = 0.76; SE 95% = 0.2 au [3.5%]). Subjective perceived recovery was estimated at posttraining, postrecovery, and 24 and 48 hours postrecovery using the methods described by Laurent et al[26] (ICC = 0.75; SE 95% = 0.3 au [3.0%]). The rating of perceived exertion (RPE) was measured before and every 40 minutes during training using the modified Borg[27] scale (ICC = 0.85; SE 95% = 0.2 au [2.4%]).

Body Temperature. As a complementary measure, we used a digital thermometer (G-Tech, Shenzhen, Guangdong, China) with an accuracy of ±0.2°C to measure skin temperature at 3 stages: pretraining, posttraining, and postrecovery.

Statistical Analysis

Exploratory data analysis was performed for identification and correction of extreme values, which was necessary only for CK. Normality and homoscedasticity were tested using the Kolmogorov-Smirnov test and the Bartlett criterion, respectively. We used analysis of variance with 2 factors (recovery × measurement time) to establish mean differences. For validation of repeated measurements, we used the Mauchly sphericity test and, when necessary, applied the Greenhouse-Geisser correction. If we observed a difference in the analysis of variance, we used a post hoc Bonferroni test. When a main effect and interaction were found, only the interaction effect was reported. The magnitude of treatment effects was calculated using the η^2 effect size. The upper and lower 95% confidence intervals (CIs) were calculated for corresponding mean variations. The standardized effect size (Cohen d)[28] analysis was used to interpret the magnitude of differences among measurements. To examine the strength of association among variables, we used the Pearson product moment correlation. The α level was set at .05 for all analyses. We used SPSS (version 15.0; SPSS Inc, Chicago, IL) to analyze the statistics.

RESULTS

Muscle Damage

The results for the serum muscle damage markers (CK, LDH, AST, ALT) in the CWI and control conditions are given in Table 1. For CK, an effect of measurement time ($F_{3,42} = 51.23$; $P < .001$, $\eta^2 = 0.785$) was found, with lower values at pretraining than at postrecovery (difference = 112.1 ± 69.3 IU/L; $P < .001$; 95% CI = 75.1, 149.0; d = 0.5), 24 hours (difference = 258.1 ± 92.5 IU/L; $P < .001$; 95% CI = 208.8, 307.4; d = 0.8), and 48 hours (difference = 113.1 ± 69.5 IU/L; $P < .001$; 95% CI = 76.1, 150.1, d = 0.6); lower values at postrecovery than at 24 hours (difference = 146.0 ± 84.4 IU/L; $P < .001$; 95% CI = 101.0, 191.0; d = 0.5); and higher values at 24 than 48 hours (difference = −144.9 ± 107.2 IU/L; $P < .001$; 95% CI = −202.0, −87.8; d = 0.6).

We observed an interaction effect for serum LDH ($F_{3,42} = 6.27$; $P = .001$, $\eta^2 = 0.309$). However, most differences were associated with the measurement time except for the lower value in the CWI than in the control condition at 24 hours (difference = 151.8 ± 136.6 IU/L; $P < .001$; 95% CI = 37.6, 265.9; d = 0.7), which was of greater interest for our study.

Serum AST showed an effect of measurement time ($F_{3,42} = 5.50$; $P = .003$, $\eta^2 = 0.282$), with lower values during pretraining than at 24 hours (difference = 5.6 ± 5.9 IU/L; $P = .009$; 95% CI = 2.4, 8.7; d = 0.7) and 48 hours (difference = 2.6 ± 6.8 IU/L; $P = .007$; 95% CI = 1.1, 6.2; d = 0.2).

We observed no effects of condition ($F_{1,14} = 0.05$; $P = .83$, $\eta^2 = 0.003$) or measurement time ($F_{3,42} = 0.44$; $P = .72$, $\eta^2 = 0.031$) for serum ALT and no interaction between condition and time ($F_{3,42} = 0.30$; $P = .82$, $\eta^2 = 0.021$).

Muscle Power

The results for CMJ and upper limb power for the CWI and control conditions are provided in Table 2. For the power generated in the bar test, an effect of interaction

Table 2. Upper and Lower Limb Power Performance at Different Times of Jiu-Jitsu Training in the Cryotherapy and Control Conditions

	Time				
Marker	Pretraining	Posttraining	Postrecovery	24 h	48 h
Upper limb power in the bar test, W					
Cryotherapy	692.0 ± 116.1	763.9 ± 157.6	599.3 ± 84.0[a]	757.9 ± 125.1	723.0 ± 90.8
Control	692.0 ± 116.1	762.0 ± 113.5	768.4 ± 97.0	695.9 ± 56.1[b]	729.8 ± 50.2
Countermovement jump, cm					
Cryotherapy	51.2 ± 6.5	54.5 ± 4.4	44.1 ± 8.1[c]	53.7 ± 3.7	53.5 ± 4.8
Control	51.2 ± 6.5	52.1 ± 4.6	52.5 ± 4.6[e]	35.5 ± 8.2[b,d]	55.7 ± 2.4[e]

[a] Indicates different from posttraining and 24 h in the cryotherapy condition ($P < .01$).
[b] Indicates different from 24 h in the cryotherapy condition ($P = .001$).
[c] Indicates different from posttraining, 24 h, and 48 h for the same condition ($P < .05$).
[d] Indicates different from posttraining, postrecovery, and 48 h in the control condition ($P < .001$).
[e] Indicates different from postrecovery in the cryotherapy condition ($P < .01$).

between condition and time was observed ($F_{4,56} = 4.68$; $P = .003$, $\eta^2 = 0.251$), with lower values at postrecovery than at posttraining (difference = −5.1 ± 8.6 cm; $P = .006$; 95% CI = −9.7, −0.5; d = 0.6) and 24 hours (difference = −8.6 ± 11.0 cm; $P = .01$; 95% CI = −14.4, −2.7; d = 0.1) in the CWI condition.

We noted an interaction between condition and time for height in the CMJ ($F_{4,56} = 13.73$; $P = .001$; $\eta^2 = 0.495$). However, most differences were associated with the measurement time, except that the values in the control condition were lower at 24 hours than at postrecovery (difference = 16.3 ± 100.2 cm; $P = .01$; 95% CI = 9.5, 26.8; d = 0.8) and 48 hours (difference = 20.0 ± 8.7 cm; $P = .01$; 95% CI = 10.7, 25.1; d = 0.8), which was of greater interest for this study.

Muscle Soreness, Perceived Recovery, and Perceived Exertion

For subjective perceived muscle soreness (Figure 3), we observed an effect of measurement time ($F_{6,84} = 31.72$; $P < .001$; $\eta^2 = 0.694$). Values were lower at pretraining than at 120 minutes (difference = 4.8 ± 2.1 au; $P < .001$; 95% CI = 3.6, 5.8; d = 0.8), postrecovery (difference = 4.8 ± 1.4 au; $P < .001$; 95% CI = 4.0, 5.5; d = 0.9), and 24 hours (difference = 2.3 ± 1.3 au; $P < .001$; 95% CI = 1.6, 3.0; d = 0.8) but not at 48 hours (difference = 1.0 ± 1.2 au; $P = .58$; 95% CI = 2.9, 1.2; d = 0.2); lower at 40 minutes than at 80 minutes (difference = 1.6 ± 1.2 au; $P = .004$; 95% CI = 0.9, 2.2; d = 0.4), 120 minutes (difference = 2.3 ± 2.0 au; $P = .009$; 95% CI = 1.3, 3.4; d = 0.5), and postrecovery (difference = 2.4 ± 1.9 au; $P = .004$; 95% CI = 1.4, 3.4; d = 0.6); lower at 24 hours than at 120 minutes (difference = 2.4 ± 2.2 au; $P < .001$; 95% CI = 1.2, 3.5; d = 0.6) and postrecovery (difference = 2.4 ± 1.9 au; $P < .001$; 95% CI = 1.4, 3.5; d = 0.7) but not at 80 minutes (difference = 1.6 ± 1.9 au; $P = .12$; 95% CI = −0.6, 4.8; d = 0.1); and lower at 48 hours than at 80 minutes (difference = 2.9 ± 2.2 au; $P < .001$; 95% CI = 1.8, 4.1; d = 0.7), 120 minutes (difference = 3.7 ± 2.4 au; $P < .001$; 95% CI = 2.4, 5.0; d = 0.7), and postrecovery (difference = 3.8 ± 2.0 au; $P < .001$; 95% CI = 2.7, 4.8; d = 0.8).

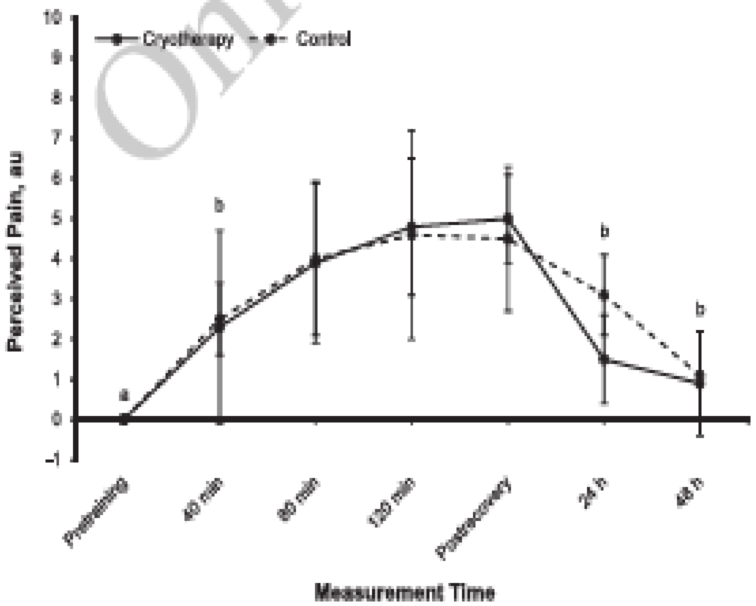

Figure 3. Perceived muscle soreness during the experimental period for cold-water immersion and control conditions. [a] Indicates different from all other times ($P < .001$) except for 48 hours. [b] Indicates different from 80 minutes, 120 minutes, and postrecovery ($P < .01$).

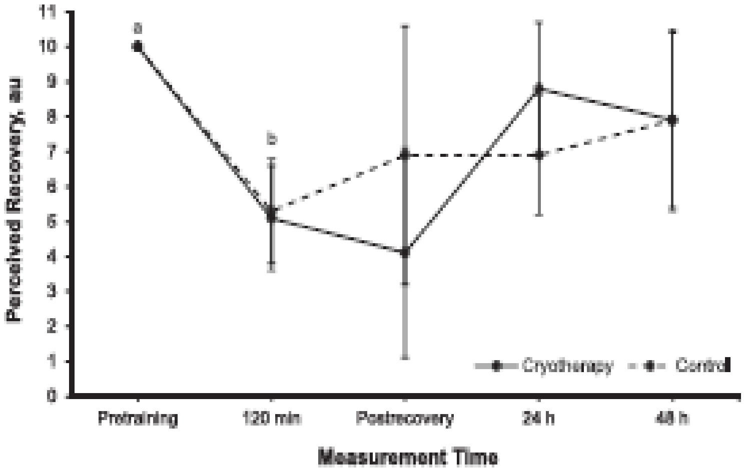

Figure 4. Perceived recovery throughout the experimental period for cold-water immersion and control conditions. [a] Indicates different from 120 minutes, postrecovery, and 24 hours ($P < .01$). [b] Indicates different from 24 hours ($P < .01$).

For the rating of perceived recovery (Figure 4), we noted an effect only of measurement time ($F_{1.92,\ 26.82} = 15.37$; $P < .001$; $\eta^2 = 0.523$), with higher recovery values at pretraining than at 120 minutes (difference = −4.8 ± 1.4 au; $P < .001$; 95% CI = −5.6, −2.1; d = 0.9), postrecovery (difference = −4.5 ± 3.6 au; $P < .001$; 95% CI = −6.4, −2.6; d = 0.7), and 24 hours (difference = −2.2 ± 2.0 au; $P = .003$; 95% CI = −3.3, −1.1; d = 0.6). The values at 48 hours were not lower than those obtained at pretraining (difference = 2.1 ± 2.5 au; $P = .054$; 95% CI = −3.5, 0.8; d = 0.5) and not higher than those obtained at 120 minutes (difference = 2.7 2.2 au; $P = .056$; 95% CI = −5.6, 4.1; d = 0.6) and postrecovery (difference = 2.4 ± 3.2 au; $P = .06$; 95% CI = −2.6, 6.4; d = 0.4). In addition, the values at 120 minutes were lower than those obtained at 24 hours (difference = 2.6 ± 2.5 au; $P = .006$; 95% CI = 1.3, 4.0; d = 0.6).

Figure 5 shows the results of RPE training in the CWI and control conditions. We observed an effect of time for RPE ($F_{3,42} = 84.39$, $P < .001$, $\eta^2 = 0.858$), with lower values at pretraining than at 40 minutes (difference = 1.5 ± 1.4 au; $P < .001$; 95% CI = 0.7, 2.8; d = 0.6), 80 minutes (difference = 3.4 ± 1.7; $P = .046$; 95% CI = 2.1, 4.5; d = 0.8), and 120 minutes (difference = 5.7 ± 1.6 au; $P = .001$; 95% CI = 4.8, 6.5; d = 0.9); lower values at 40 minutes ($P < .001$) than at 80 minutes (difference = 1.9 ± 1.1 au; $P = .002$; 95% CI = 0.9, 2.2; d = 0.4) and 120 minutes (difference = 4.2 ± 1.6 au; $P = .002$; 95% CI = 2.9, 5.0; d = 0.8); and lower values at 80 minutes than at 120 minutes (difference = 2.3 ± 1.3 au; $P = .012$; 95% CI = 1.5, 3.2; d = 0.6).

The correlations between perceived muscle soreness and lower limb power ($r = -0.587$, $P = .02$) and between serum LDH levels and lower limb power ($r = -0.626$, $P = .01$) are shown in Figure 6. We observed an effect of condition for

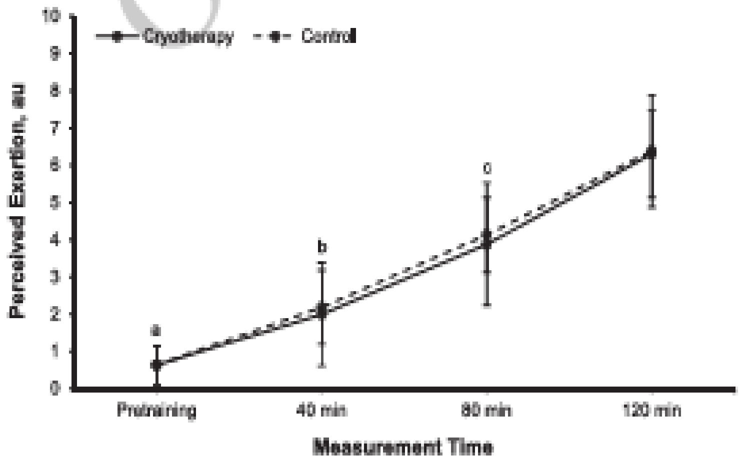

Figure 5. Ratings of perceived exertion throughout training for cold-water immersion and control conditions. [a] Indicates different from other times regardless of condition ($P < .001$). [b] Indicates different from 80 minutes and 120 minutes regardless of condition ($P < .001$). [c] Indicates different from 120 minutes regardless of condition ($P < .001$).

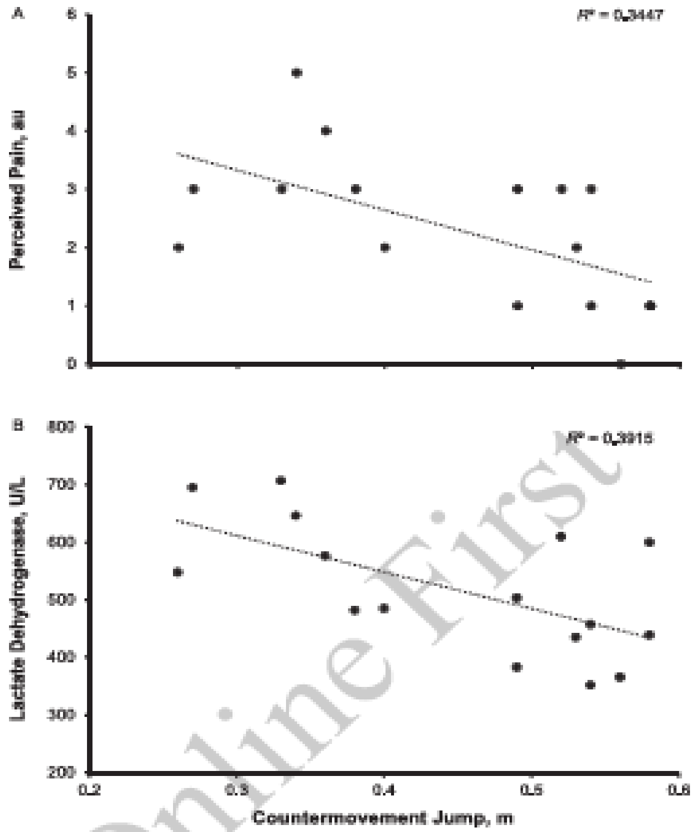

Figure 6. Countermovement jump. A, Correlation between perceived muscle soreness and power of lower limbs. B, Correlation between serum lactate dehydrogenase concentration and power of lower limbs.

body temperature ($F_{1,14}$ = 22.47; P = .003; η^2 = 0.616), with lower values in the CWI than control condition (P < .001). We also observed an interaction effect ($F_{1,14}$ = 13.63; P = .002; η^2 = 0.493), with lower values after the CWI condition (35.3°C ± 0.5°C) than at pretraining during the CWI condition (37.9°C ± 1.1°C; P < .001; 95% CI = 1.6, 3.6; d = 0.8) and control condition (37.3°C ± 1.2°C; P < .001; 95% CI = 0.7, 3.2; d = 0.8) and in the control condition at posttraining (36.9°C ± 0.5°C; P = .004; 95% CI = 1.2, 2.1; d = 0.9).

DISCUSSION

Competitive jiu-jitsu requires high training volumes, and the establishment of recovery strategies can help the athlete maintain training volumes, reducing the injury risk during competitive preparation.[17] The aim of our study was to measure the effect of posttraining CWI on the recovery of jiu-jitsu athletes. Among the main results, CWI resulted in lower serum LDH concentrations at 24 hours postrecovery. It also resulted in decreased power at immediate post-recovery compared with posttraining, with restoration of values at 24 hours postrecovery. Lower limb power returned to pretraining values at 24 hours postrecovery only in the CWI condition. Perceived muscle soreness was not affected by conditions and was affected only by measurement time; the sensation of muscle soreness remained high compared with pretraining up to 24 hours after the training session, returning to baseline within 48 hours. Perceived recovery was not affected by the intervention, with a decrease at posttraining and restoration within 48 hours. These differences cannot be attributed to training efforts because the sessions were the same in both conditions and the RPE did not differ between them. Perceived muscle soreness and serum LDH levels were negatively correlated with lower limb power. In addition, CWI effectively reduced body temperature compared with the control condition. Whereas CWI is widely used in sports, its physical and physiologic effects on athletes suggest the existence of a placebo effect associated with this regenerative practice.[14] Researchers have shown that CWI may be beneficial for jiu-jitsu athletes engaged in training[17] and competition cycles[8] because it reduced the perceived muscle soreness and the serum concentration of enzymes indicative of serum muscle damage (CK and LDH).

Serum CK and LDH are enzymes important for anaerobic metabolism, and the leakage of these enzymes into the plasma has been associated with muscle damage and delayed-onset muscle soreness.[29] In contrast to our results, the meta-analysis of Leeder et al[14] showed an effect of CWI on postrecovery serum CK concentrations. Ascensão et al[30] reported lower serum CK levels 24 hours after a simulated soccer game when players underwent CWI (10 minutes at 10°C). The low temperature of the liquid medium reduces skin temperature and peripheral vasoconstriction, reducing peripheral blood flow that, in turn, reduces the release of metabolites arising from inflammation and neural signaling. These peripheral changes from the low temperature of the liquid medium result in less muscle soreness signaling.[31] Whereas the analgesic effect of CWI has not been fully explained,[12] investigators[32] believe that the smaller nerve conduction decreases the firing rate of the muscle spindle and afferent responses, thereby decreasing pain and spasm. Yanagisawa et al[33] observed that cryotherapy increases intracellular pH, delaying the onset of muscle edema, but other physiologic effects, such as the release of interleukin-6, can occur in the muscles.[34]

Grappling sports, such as jiu-jitsu, require high power demand,[35] and highly trained athletes possibly have neuromuscular adaptations that increase efficiency in the energy supply from anaerobic pathways.[36] Athletes who demand energy from the glycolytic pathway potentially recruit alanine and glutamine for the synthesis of adenosine triphosphate, thereby increasing the activity of serum AST and ALT enzymes.[37] In fact, increased serum ALT after a single 7-minute jiu-jitsu match has been reported.[38] In addition, during prolonged exercise, these enzymes catabolize amino acids for use as energy in the Krebs cycle.[10] Between the starting and post-CWI times, serum AST increased approximately 22% and 25.5% in the CWI and control conditions, respectively; however, at 24 hours postrecovery, it remained high only in the control condition. An increase in the posttraining serum AST concentration was observed in Japanese judo athletes who performed 120 minutes of training. According to Andreato et al,[35] a jiu-jitsu match requires a moderate energy supply from the glycolytic pathway, which explains the increased demand for this enzyme during training, but other energy sources are also used. According to Andreato et al,[38] glycogen is not the only source of energy used during a jiu-jitsu match, and proteolytic and lipolytic activation also occur. Among the enzymes used to estimate muscle damage in our study, only serum LDH showed an interaction, and the CWI condition showed advantages over the control condition. In fact, the effect of CWI on these enzymes is not completely understood in the literature. The authors[13,14] of meta-analyses affirmed that the main physiologic effect found in cryotherapy studies was the reduction of pain.

At immediate postrecovery, we observed less lower and upper limb power in the CWI condition. Nazari et al[10] also noted less muscle stress and elasticity after the application of ice packs to the quadriceps. However, at 24 hours postrecovery, lower limb power in the CWI condition returned to baseline, corroborating the results of Glasgow et al.[39] In rugby players, CWI resulted in recovery of the maximal voluntary isometric contraction at 24 hours postrecovery.[40] Whereas the mechanisms explaining recovery are not completely elucidated, Ihsan et al[41] suggested that CWI decreases intramuscular infusion and the metabolism of fibers; however, this process does not affect muscle recovery. Accordingly, Gregson et al[42] observed that CWI does not affect the recovery of muscle glycogen. Although it delays some muscle regeneration, power recovery is greater when individuals undergo cryotherapy, and further studies are needed to clarify how postcryotherapy muscle strength is restored.[43] We observed varied responses to the 4 muscle-damage enzymes measured. We measured the effect of CWI on AST and ALT enzymes in combat-sport athletes. Despite the increases that we observed and that Umeda et al[44] observed after a typical judo training session, Yamamoto et al[45] measured lower serum levels of AST, LDH, and CK posttraining in judokas engaged in a long-term training period (6 months), suggesting that one important adaptation of long-term training is less or no muscle damage. Whereas few investigators have measured the AST and ALT enzymes, Yamamoto et al[45] reported increased values in judo athletes at immediate posttraining but not at 24 hours postrecovery. We did not measure several factors that modulate the CK response, including changes in plasma volume, the difference between the rate of release of CK into and its removal from the blood,[30] and polymorphisms of the actinin-3 and myosin light chain kinase genes.[19]

In our study, serum LDH was inversely associated with lower limb power. Pinho Júnior et al[8] observed an inverse correlation between serum LDH and perceived muscle soreness ($r = -0.53$) and upper limb power ($r = -0.32$) in jiu-jitsu athletes who underwent CWI after simulated competition. Detanico et al[1] reported an increase in serum LDH levels and less lower limb power in judo athletes after 3 successive matches. According to Warren et al,[46] strenuous exercise caused structural disruption of sarcomeres, resulting in membrane damage and failures in the coupling process triggering muscle contraction. The lower serum LDH level and less perceived muscle soreness are possibly associated with faster recovery of muscle homeostasis. Gregson et al[31] noted that CWI decreased peripheral temperature and resulted in less muscle osmotic pressure, which affected the release of metabolites resulting from exercise (eg, muscle enzymes), propagating lower pain afferent signaling.

A possible bias in our study was the absence of direct measures of exercise intensity, which is a variable that is difficult to monitor in studies involving combat-sport athletes.[47] However, the RPE did not differ in our athletes when training before the different recovery protocols. Future researchers could focus on the effect of CWI or other forms of cryotherapy on the specific performance of combat-sport athletes.

The recovery process after training and competition is paramount in athletic preparation. Combat-sport athletes normally perform 2 training sessions per day, 6 days per week.[14] Thus, improving athletes' physiologic state and performance potential is important to ensuring that training goals will be achieved more efficiently. Among the recovery interventions recommended and used by athletes is cryotherapy. We demonstrated that intermittent exposure (four 4-minute immersions interspersed by 1-minute intervals) to cold water (6.0°C ± 0.5°C) improved the posttraining recovery of jiu-jitsu athletes. Specifically, CWI resulted in a lower level of a muscle-damage marker (serum LDH) and improved both upper and lower limb muscle power performance at 24 hours postrecovery compared with the control condition. These changes were accompanied by decreased perceived muscle soreness and a higher rating of perceived recovery. Thus, coaches and athletic trainers could apply this recovery intervention to improve physiologic status and performance, especially during training phases in which more intensive sessions are conducted and at the beginning of the season. We emphasize that our results were obtained after a single training session; future researchers should focus on the long-term results of cryotherapy on performance and on injury prevalence during the competitive season. We studied highly trained athletes; however, the effects of CWI can last longer in athletes who train at lower levels. In healthy individuals, Selkow et al[12] observed less perceived pain 48 hours after CWI. Given that our results provided evidence of a positive effect of CWI on serum LDH levels, muscle soreness, and upper and lower body performance until 24 hours, this approach can be useful when athletes are submitted to periods of intensified training.

CONCLUSIONS

Considering the objectives established and the results obtained with the methods applied, we conclude that CWI (at approximately 6°C) may be beneficial to jiu-jitsu athletes because it decreases serum LDH levels, reduces the perception of muscle soreness, and assists in the recovery of upper and lower limb power 24 hours after a training session.

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2.2 Estudo 2 :Lillian Beatriz Fonseca, Felipe J Aidar, Dihogo de Matos Gama, Natalie de Almeida Barros, Raphael Fabricio de Souza, Alan Santos de Oliveira, Marcelo Danillo Matos dos Santos, Victor Machado Reis, Analysisofmuscledamageandstrength in training e competitionsimulationJiuJitsuathletes. Medicinadello Sport (Submetido, Extrato A2)

Abstract

Background: The objective was to analyze muscle damage, strength and their correlation at two distinct conditions, a specific training session and a competition simulation session.

Methods: The study sample included nine subjects, aged 22.50 ± 2.84 years, with a height of 1.77 ± 0.05 m, body mass of 75.45 ± 6.86 kg, and body fat of 14.45 ± 3.36 %. All the participants were submitted to the following two interventions: 1. simulation of training and 2. simulation of competition.

Results: There were no significant differences in relation to the SJ test at different time points in the applied methods. It can be observed that there were no significant differences in the CMJ test; however, 48 h after the training, higher values than those in the week of the competition were observed. Regarding CPK levels, there were significant differences after competition in relation to the other time points and intervention ($p = 0.004$), with a high effect. The LDH levels, there were significant differences in post-competition and pre-competition in relation to pre- and post-training ($p = 0.019$), with a high effect. It was observed that the PUL results showed a median correlation 24 (0.554) and 48 h (0.473) after the intervention. The SJ test results showed a high correlation (0.716), and the other test results showed a very high correlation (>0.8). All variables presented a very high correlation at both time points of the study. Only the variable LDH level, 48 h later, presented a high correlation.

Conclusion: It was concluded that a good correlation exists between training simulation and competition simulation, where the model adopted as training can meet the needs imposed in the competition.

Key words: Muscle damage – JiuJitsu – Strength - Competition

BACKGROUND

In combat sports competitions, the number of fights to which athletes are submitted and their respective durations and intervals are random; these factors may influence the performance, in addition to the factors related to the physiological, technical, and tactical part of each sporting modality (Andreato et al., 2013, 2014).

On the other hand, training in all sports tends to maintain the athletic performance during the competitive period, where the plasticity of skeletal muscle tissue aims at adapting to various functional demands of each sporting modality (Palmeret al., 2015; Lesinski, Prieske, Granacher, 2016), and where the training aims to increase the tolerance to the exercise, triggering adaptive processes of mechanical, metabolic, and electrophysiological characteristics (Lafay et al., 2009; Racinais et al., 2015) according to the requirements of each modality.

Thus, to maintain the pace of training for a high-performance athlete, it is necessary to exert a great physical effort during physical preparation (Detanico, Dal Pupo, Franchini & dos Santos, 2014). This effort generates a series of biochemical and cellular changes that result in deterioration of the muscular structure, which could generate a deficit in the maintenance of these activities (Byrne & Eston, 2002, Torres, Ribeiro et al., 2012), leading to a specific adaptation to competitive conditions.

To understand these effects, it is necessary to study the muscle damage generated during physical activity (Torres, Ribeiro et al., 2012). Among the most investigated muscle damage markers are creatine phosphokinase (CPK), lactate dehydrogenase (LDH) (Clarkson and Hubal, 2002), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) (Chishaki, Umeda et al., 2013). An increase in CPK caused by the practice of exercises is directly related to the onset of late muscle pain, as well as to the greater expression of cartilage injury markers (Nazari, Azarbayjani, Azizbeigi, 2016, Fonseca et al., 2016).

Although several studies have evaluated Jiu-Jitsu, and addressed questions related to training and competition by studying physiological variables, the few studies that have evaluated training specificity and its relationship with competition variables have reported highly contradictory results (Andreato, Lara, Andrade, Branco, 2017; Brandão et al., 2014). In this context, the objective of our study was to analyze muscle damage,strength and their correlation at two distinct conditions, a specific training session and a competition simulation session.

MATERIALS AND METHODS

A crossover model was used for the study, where two training sessions were separated by 1-week intervals. The procedures of data collection are described in Figure 1. The training protocol included a typical session characterized by progressive and exhaustive effort. Each training session comprised the following structure: 40 min each of the following modules: generalized exercises (calisthenics), technical training, and combat simulation, amounting 90 min of training. Widespread exercises included warm-up exercises involving aerobic activities such as races and speed and counter resistance exercises using body weight. Technical training focused on specific movements of Jiu-Jitsu such as guard passes, projections, scraping, immobilizations, and submission. The combat simulations occured with 6-min fights, totaling three fights for each individual with a 10-min interval between fights. This training model was adapted in other studies on Jiu-Jitsu (Diasz-Lara *et al*., 2016, Andreato*et al*., 2015, Fonseca *et al*., 2016). Volunteers were familiar with the training regimen.

Figure 1: Design of the procedures performed in the study

Anthropometry	Muscle Test BloodCollection	Tests	Muscle Test BloodCollection	Muscle Test BloodCollection	Muscle Test BloodCollection

	Warm	Technique	Tactical
Training Simulation (Week 1)	 40 minutos	 40 minutos	 40 minutos

	Simulation	Rest	Simulation	Rest	Simulation
CompetitionSimulation (Week 2)	 6 Minutes	10 minutes	 6 Minutes	10 minutes	 6 Minutes

0 40 80 120 140 24 48

Pretraining	minutes	minutes	minutes	minutes	minutes	hours	hours

Sample

The study sample included nine subjects, all males with at least 12 months of Jiu-Jitsu experience, who participated in official competitions in the last 6 months at regional and national levels. These subjects were aged 22.50 ± 2.84 years, with a height of 1.77 ± 0.05 m, body mass of 75.45 ± 6.86 kg, and body fat of 14.45 ± 3.36 %. All the participants were submitted to the following two interventions: 1. simulation of training and 2. simulation of competition. Each subject performed the two exercise conditions in random order.

The inclusion criterion was not using any type of stimulants or involving in any rapid weight loss process before the intervention, because this practice could negatively affect the physical performance (Fonseca et al., 2016), and these facts were confirmed by an interview with the subjects. Participation in the study was subject to medical authorization, and only clinically healthy subjects were included.

All subjects were submitted to two familiarization sessions and two for the tests with a minimum rest interval of 72 h between sessions. All subjects were informed about the study, and all of them signed the authorization (free, informed and consent) in accordance with resolution 466/2012 of the National Commission of Ethics in Research - CONEP, National Health Council, according to the ethical principles of the Declaration of Helsinki (1964, reworded in 1975, 1983, 1989, 1996, 2000, 2008, and 2013) of the World Medical Association.

The study was approved by the Research Ethics Committee of the Federal University of Sergipe (protocol 01723312.2.0000.0058), according to the Council on experiences with humans.

Instruments

Body mass, height, and body fat

A digital platform scale (Fillizola 2002, Filizola, Brazil) calibrated from 0 to 150 kg, with an accuracy of 0.1 kg, was used to measure the weight in kilograms (kg).

Measurement of height was done in triplicate for the calculation of the mean value, using a tape type ES2040 (Sanny, Brazil) compact stadiometer, fixed to the wall, with a capacity of 2.0 m and an accuracy of 0.1 cm (Picon et al., 2007, Giugliano and Melo, 2004).

Body density was measured using a scientific adipometer of the Sanny® brand (Sanny, Brazil) and was obtained by the quadratic equations of three skinfolds of Jackson & Pollock (1978) for men, followed by the equation of Siri (1956), to estimate the percentage of body fat.

Muscle damage

Serum concentrations of CPK, LDH, AST, and ALT were used as indicators of muscle damage.

Blood samples (8.0 ml) were drawn from the antecubital fossa vein before, immediately, and after 24 and 48 h post-intervention and were deposited in tubes containing a coagulant gel (Vacuette®, Greiner Bio-one, Brazil).

Biochemical measurements were performed using the Vitros® 5600 film system (Ortho-Clinical Diagnostics, Johnson & Johnson Company, USA). LDH, AST, and ALT levels were measured by the multipoint kinetic technique. The CPK level was measured by the multipoint rate technique.

Squat jump and countermovement jump

For the evaluation of the squat jump (SJ) and countermovement jump (CMJ) tests, a 50 × 60 cm conductive surface contact mat (Probotics Inc., USA) was used that was connected to a display (Probotics Inc., USA). The height of the vertical jump resulting from the time interval between the loss of contact of the feet with the carpet and the subsequent contact after the fall was measured (Bosco, 1983).

Muscle power test

All athletes performed muscle power test using a suppressed footprint bar and an encoder attached to their Musclelab Encoder belts (Model PFMA 3010e Muscle Lab System; Ergotest, Langesund, Norway).

Procedures

Body density

Body density was estimated indirectly (Lange Skinfold Caliper; Beta Technology, Santa Cruz, CA) using the equation of Thorland et al. (1991) for college wrestlers as follows:

$$D\ (g/mL) = 1.1030 - [0.000815(SD)] + [0.00000084(SD)];$$

Where D is the body density and SD is the sum of subscapular and abdominal skinfold thicknesses. Body fat percentage (BF%) was estimated using the equation of Brozek et al. (1963) as follows:

$$BF\% = 457/D - 414.2$$

Muscle damage

The markers of muscle damage, i.e., serum CK, LDH, AST, and ALT concentrations, were measured. Blood samples were collected during the pre- and post-training periods, post-intervention, and 24 and 48 h after intervention. A total of 8 mL of blood was collected from the antecubital vein and stored in tubes containing coagulant gel (Vacuette; Greiner Bio-One, Campinas, São Paulo, Brazil). The blood was kept for 30 min at room temperature for coagulation and then centrifuged at 4,000 rpm for 8 min to separate the serum. Biochemical measurements were performed on an automated analyzer (Vitros model 5600; Ortho Clinical Diagnostics, Raritan, NJ, USA).

Serum LDH (coefficient of variation for the same sample of 1.2%, precision of 1.909 IU/L), serum AST (coefficient of variation for the same sample of 1.8%, precision of 1.781 IU/L), and serum ALT (coefficient of variation for the same sample of 1.9%, precision of 1.909 IU/L) levels were measured using the multipoint kinetic technique. Serum CPK level was measured by the multipoint rate technique (coefficient of variation for the same sample of 1.5%, accuracy of 8.456 IU/L).

Power in upper limbs (PUL)

During pretraining, post-recovery, and 24 and 48 h after recovery, all athletes performed muscle power test using a bar with the footprint in the supinated position where three repetitions were performed, and the best result was selected for analysis. The reliability calculation was performed from baseline and intraclass coefficient (ICC) of 0.96 and a standard error (SE, 95%) of 16.4 W (2.1%). The initial and final positions of the upper limbs during the power test were performed according to the methodology described by Fonseca et al. (2016).

SJ and CMJ

During pretraining, post-recovery, 24h, and 48h after recovery post-collection, all participants performed a potency test of the lower limbs. For the evaluation of both jumps, the athlete stood on the mat, the weight being evenly distributed on both feet and the hands placed on the hip, and must remain throughout the test. To execute the SJ upon hearing the “ready” command, he crouched down by flexing his knees at a 90° angle, and after the “Go” command, he made the vertical jump as high as possible, keeping his knees in extension. For the CMJ, the jump movement was performed after a single “Go” command starting from a standing position, followed by a squat to push in the execution of the vertical jump. The SJ and CMJ were evaluated before and after the intervention (Bosco, 1983).

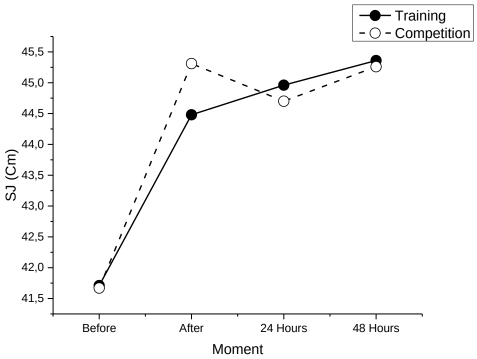
For the jumps, the subjects made two attempts, and the best result was used for analysis. For the lower limbs, we calculated the reliability of the baseline replicates and found ICCs (0.96 and 0.95, respectively) and SEs (95% for both) of 1.23 and 1.39 cm, respectively (1.9% and 2.4%, respectively).

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS), version 22.0. The central tendency measures, mean ± standard deviation, were used. To verify the normality of the variables, the Shapiro–Wilk test was used, considering the sample size. To verify the possible differences between the groups divided by the age group, the two-way ANOVA (type of intervention and time point) was used. The post hoc Bonferroni test was used for assessing the indicators of strength and muscle damage. Pearson’s correlation coefficient “*r*” was used to correlate the post-training and post-competition results To verify the effect size, the Cohen f^2 test was used, in addition to the cut points from 0.02 to 0.15, with a small effect from 0.15 to 0.35 as median and greater than 0 (Grissom and Kim 2005). Statistical significance was considered at $p < 0.05$.

RESULTS

Figures 1–7 show the results of muscle damage, i.e., the levels of CPK, LDH, AST, and ALT, and the results of the SJ and CMJ tests as well as the PUL test at pre- and post-test and 24 and 48 h after intervention through training simulation and competition, along with their kinetics.



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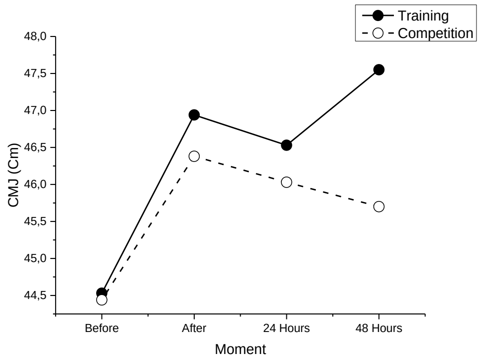
gure 1: Squat Jump (SJ) in training simulation and competition simulation



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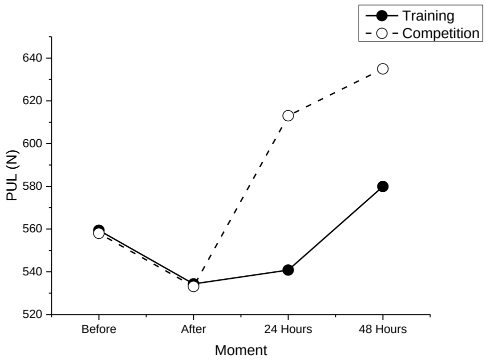
gure 2: Counter Movement Jump in training simulation and competition



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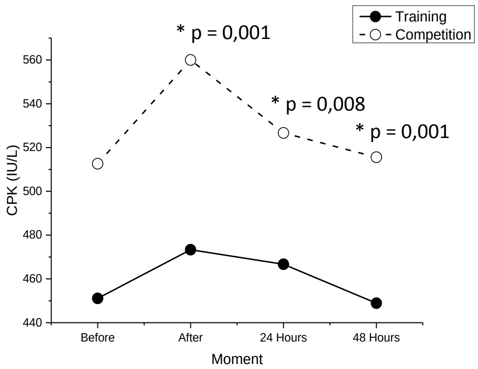
gure 3: Power in Upper Limbs (PUL) in training simulation and competition



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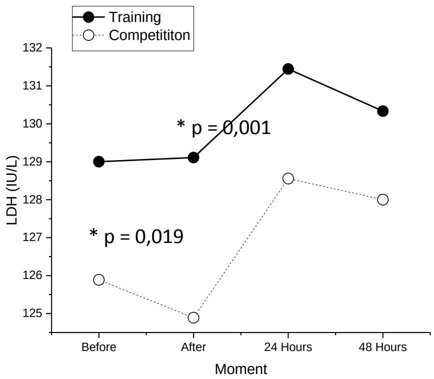
gure 4: CPK in training simulation and competition



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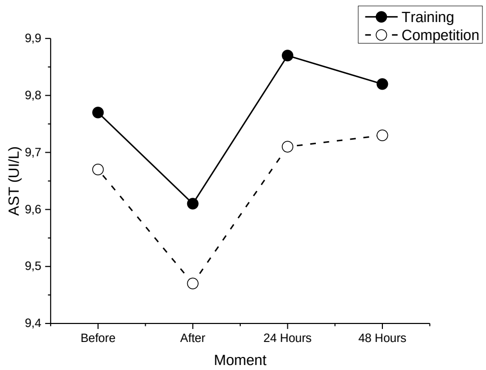
gure 5: LDH in training simulation and competition



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gure 6: AST in training simulation and competition

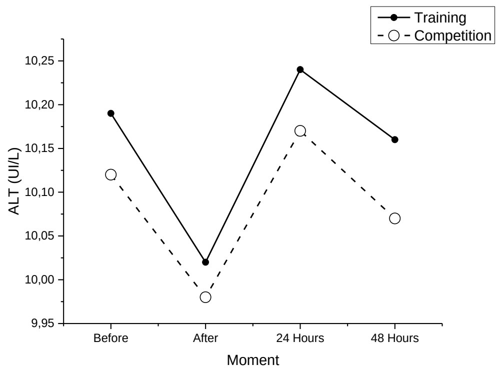

Figure 7: ALT in training simulation and competition

Figure 1 shows that there were no significant differences in relation to the SJ test at different time points in the applied methods. In Figure 2, it can be observed that there were no significant differences in the CMJ test; however, 48 h after the training, higher values than those in the week of the competition were observed. Regarding the PUL test (Figure 3), the results were in contrast to the CMJ test, where the values, although there were no significant differences at the different time points, 48h after the competition were higher than those in the training period ($p > 0.990$). Regarding CPK levels (Figure 4), there were significant differences after competition in relation to the other time points and intervention ($p = 0.004$), with a high effect. Regarding LDH levels (Figure 5), there were significant differences in post-competition and pre-competition in relation to pre- and post-training ($p = 0.019$), with a high effect. The other variables did not present significant differences both at the different time points and between the training intervention and competition. The AST and ALT levels showed no significant differences and presented a very similar kinetics, and the values were also similar (Figure 6 and 7).

Table 1 describes the correlation at the different time points between the training and the combat simulation.

Table 1: Correlation between training and competition in Squat Jump (SJ), Counter Movement Jump (CMJ), Power in Upper Limbs (PUL), and muscle damage (mean±standard deviation)

Moment	Training simulation	Combat simulation	*R*
SJ (Cm)	41,73±3,28	45,31±6,10	0,716*

SJ (Cm) 24 hours	44,99±4,75	44,70±6,10	0,748*
SJ (Cm) 48 hours	45,36±5,33	45,26±6,05	0,874#
CMJ (Cm)	44,43±5,11	46,38±6,93	0,801#
CMJ (Cm) 24 hours	46,53±6,07	46,03±5,74	0,934#
CMJ (Cm) 48 hours	47,55±7,87	45,70±5,41	0,861#
PUL (W)	558,13±44,89	533,15±96,37	0,922#
PUL (W) 24 hours	540,81±159,18	613,02±89,40	0,554
PUL (W) 48 hours	579,90±166,41	634,96±90,74	0,473

* High correlation, # Very high correlation

It was observed that the PUL results showed a median correlation 24 (0.554) and 48 h (0.473) after the intervention. The SJ test results showed a high correlation (0.716), and the other test results showed a very high correlation (>0.8).

Table 2 describes the correlation at the different time points between the training simulation and the combat simulation (CPK, LDH, AST, and ALT levels).

Table 2: Correlation between training and competition simulation in the muscle damage variables CPK, LDH, AST and ALT tests (mean ± standard deviation)

	Training simulation	Combat simulation	*R*
CPK (UI/L)	473,33±22,36	560,00±55,23	0,982#
CPK (UI/L) 24 horas	466,67±26,46	526,67±50,00	0,917#
CPK (UI/L) 48 horas	448,89±32,19	515,56±75,68	0,988#
LDH (UI/L)	129,11±1,96	124,89±2,15	0,922#
LDH (UI/L) 24 horas	131,44±3,36	128,56±4,22	0,969#
LDH (UI/L) 48 horas	130,33±2,96	128,00±2,60	0,748*
AST (UI/L)	9,61±0,33	9,47±0,30	0,988#
AST (UI/L) 24 horas	9,87±0,42	9,71±0,42	0,992#
AST (UI/L) 48 horas	9,82±0,39	9,73±041	0,989#
ALT (UI/L)	10,02±0,31	9,98±0,32	0,986#
ALT (UI/L) 24 horas	10,24±0,27	10,17±0,38	0,888#
ALT (UI/L) 48 horas	10,16±0,68	10,07±0,69	0,996#

* High correlation, # Very high correlation

All variables presented a very high correlation at both time points of the study. Only the variable LDH level, 48 h later, presented a high correlation.

DISCUSSION

The present study aimed to analyze the muscle damage, strength and their correlation that could exist in the Jiu-Jitsu modality at two different time points.

It was verified that in relation to the strength measured by the SJ, after training (41.73 ± 3.28 cm) and post-competition (45.31 ± 6.10 cm), the correlation was r = 0.716, and after 24 (r = 0.748) and 48 h (r = 0.874), the correlation was still higher. Regarding CMJ, the correlation at all time points was higher than 0.800, demonstrating that there is a correlation between training and competition for the various types of strength manifestations. However, regarding the PUL, there was a correlation after the training (558.13 ± 44.89 W) and after the competition simulation (533.15 ± 96.37 W).

However, after 24 h, the recovery did not occur with the same kinetics, with different values in the training (540.81 ± 159.18 W) and competition (613.02 ± 89.40 W) with an intermediate correlation (r = 0.554), and after 48 h, the correlation was lower (r = 0.473). These results demonstrate that competitive efforts tend to be higher in relation to upper limbs, and the requirements in competition tend to be more stressful in this follow-up than those in training.

The fatigue effects in the lower limbs can be attributed to intense isometric, concentric, and eccentric actions performed during the matches (Diaz-Lara et al., 2014, 2016), such as guard passes, sweeps, and leg submissions. It has been documented that the actions performed at high intensity and with short rest periods, primarily in the eccentric mode, produce immense overload and mechanical stress on muscular structures (Byrne &Eston, 2002; Twist &Eston, 2005). During a simulated judo contest, Detanico et al. (2015) found a decrease in vertical jump performance after three matches, and this was explained by the powerful eccentric actions performed by the legs during that combat, which caused impairments in muscle function.

On the other hand, another study demonstrated that, through training procedures with recovery in ice water, the PUL showed significant differences 24 h after the training, and the values presented were superior to the present study values, with recovery in cold water (757.9 ± 125.1 W) and in the control group (695.9 ± 56.1 W) (Fonseca et al., 2016).

Regarding muscle damage, a high correlation was observed in all indicators of CPK damage (r> 0.9) at all time points after training simulation or combat simulation. In the same context, it was verified that in CPK levels, significant differences were found at the time point after all the time points in the competition in relation to the training (post-training 560.00±55,23 to 473.33±22,36, 24 h 526.67±50,00 to 466.67±26,46, and 48 h after 515.56±75,68 to 448.89±32,19), respectively. The results of the present study corroborate with those of other studies that found an increase in serum concentrations of post-exercise CPK, which was inversely proportional to the capacity of the muscle to generate strength (PinhoJúnior, Brito et al., 2014). On the other hand, another study that evaluated muscle damage after training also identified CPK levels to be more altered (Fonseca et al., 2016).

Regarding LDH levels, a high correlation between training and combat was observed ($r > 0.9$ in the post-training and after 24 h, and $r = 0.748$ after 48 h). On the other hand, LDH is present in large quantities in the skeletal muscle, as this enzyme is responsible for the anaerobic conversion of pyruvate to lactate. The association of LDH with muscle damage is closely linked to increased CPK concentration (Hausswirth, Louis et al., 2011), which would explain the results of our study.

Regarding AST and ALT levels, the correlation between training and the combat was high ($r > 0.888$ at all time points after). AST and ALT are important liver enzymes for amino acid catabolism, and although not concentrated in the muscle, increased activity of these enzymes occurs during intense exercise (Nazari, Azarbayjani, Azizbeigi, 2016) or intermittent exercise (Samadi et al., 2012), since intense exercise tends to increase protein catabolism. However, no major changes in AST and ALT levels were found in our study. In addition, regarding CPK and LDH levels, a study using other grappling methods found an increase of 15%–42% in the serum concentration of these enzymes after 2.5 h of training (Kubo et al., 2006).

CONCLUSION

It can be concluded that there is a great correlation between as force-related and biochemical variables related to the damage both in the training simulation and in the simulation of competition.. Regarding muscle power, we noticed that the methods used in the training of the upper limbs should be reviewed, since these limbs showed signs of a greater wear after the simulated competition than that observed in the training session.

To summarize, a good correlation exists between training simulation and competition simulation, where the model adopted as training can meet the needs imposed in the competition and may undergo changes to better approach the true conditions found in a competition.

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3. Conclusão Geral

Sendo o Jiu-Jítsu um esporte de alta intensidade, onde as sessões de treino e competições geram danos que diminuem as atividades musculares dos atletas, testamos a Crioterapia como ferramenta para auxiliar na recuperação pós treino e avaliamos a correlação entre uma sessão de treino e uma competição, diante dos nossos resultados, podemos concluir que a Crioterapia, através do método da imersão em água gelada tende a acelerar a recuperação dos atletas de Jiu-Jítsu no que se refere a potência de membro superiores e inferiores, além de diminuir a evidência marcadores de dano muscular quando comparada a uma recuperação passiva.

Conclui-se também que o método de treino utilizado consegue suprir a demanda energética exigida durante uma competição, podendo este, sofrer alterações que visem cada vez mais proporcionar aos atletas uma preparação física condizente com a realidade de uma competição. Acreditamos que mais estudos sobre o tema seriam de total importância para promover cada vez mais benefícios aos praticantes da modalidade.

Contudo, nosso estudo tende a beneficiar profissionais e atletas de Jiu-Jítsu que poderão usar a Crioterapia no auxilio da recuperação, além de proporcionar embasamento para uma melhor adaptação de treinos e programas de treinamento facilitando a manutenção das atividades em busca dos objetivos competitivos pré-estabelecidos.